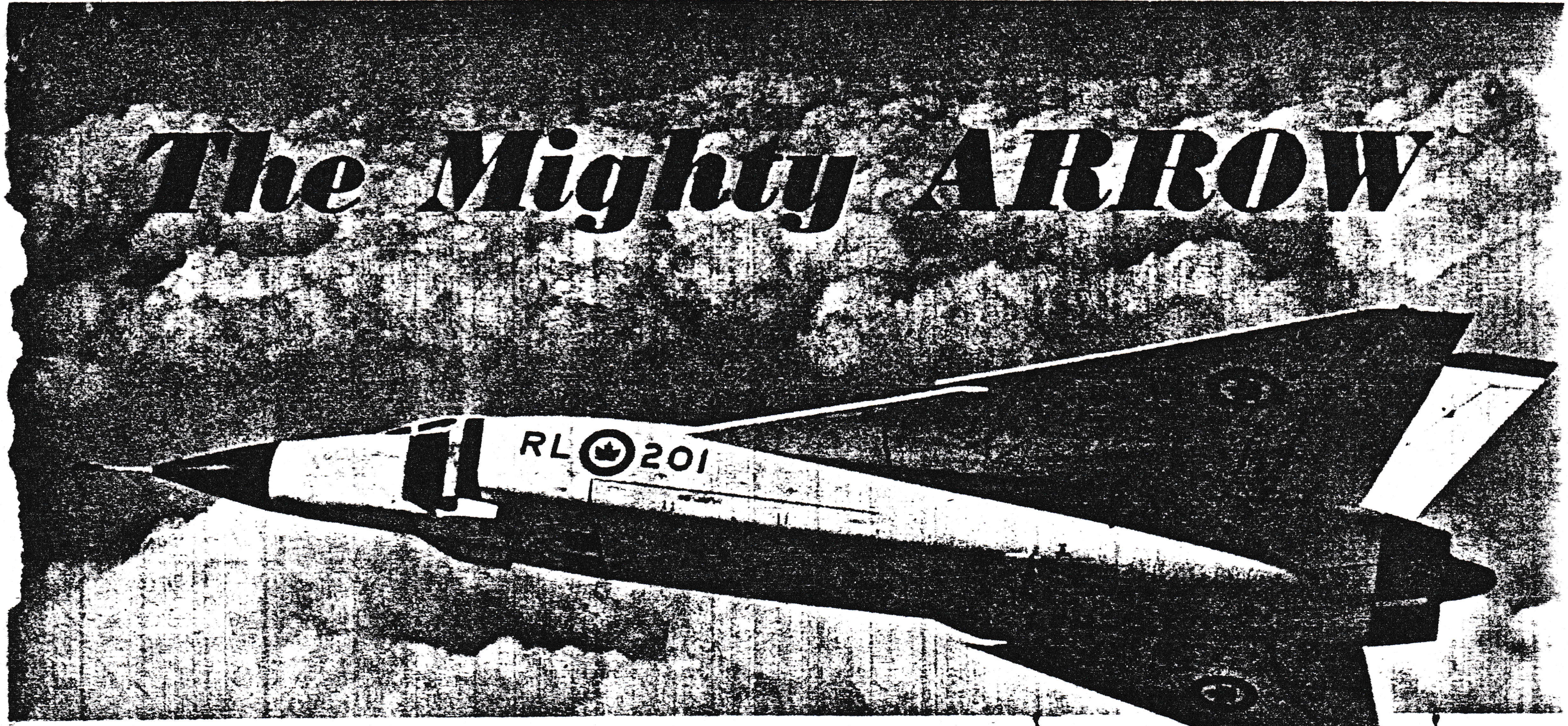
The Mighty ARROW



A vital decision faces Canada's Government—and on it hangs the fate of the world's most powerful fighter . . . described here by WILLIAM GREEN

The current programme calls for the completion of six Arrows, including the first Mk. 2, by March, although it is anticipated that, by that time, four additional Arrow Mk. 2s will be either flight testing or in the pre-flight test stage.

DESPITE the official decision to re-assess its place in Canada's over-all defence system, Avro's mighty Arrow—the largest, most powerful and potentially the fastest fighter yet flown—is currently improving upon the most sanguine of performance predictions. It bids fair to becoming the first combat aircraft capable of bettering Mach 3.0 in level flight.

The Arrow programme is currently the major military project in Canada and involves almost all of the Canadian aircraft and associated industries. It is not surprising, therefore, that it is now the subject of an all-out struggle, for upon the result depends the Canadian aircraft industry's future capacity for the original design of high-performance aircraft.

Originally scheduled to provide the backbone of Canada's air defence in the 'sixties, the Arrow has become a source of national pride, and if the doubts regarding the production future of this interceptor, first raised in September by Prime Minister Diefenbaker, bear fruit in its cancellation, it will undoubtedly be looked upon as a national calamity. In a statement concerning a review of the Canadian Air Defence Programme, Mr. Diefenbaker revealed that it had been decided to introduce Boeing's IM-99 Bomarc surface-to-air missile into the air defence system and that this would result in the need for substantially fewer supersonic interceptor aircraft if, in fact, such aircraft were to be required at all in the 'sixties !

The result was the immediate cancellation of the RCA Astra integrated electronic system intended for the Arrow—a highly sophisticated system providing automatic flight control, airborne radar, telecommunications and navigation—together with the Sparrow II homing missiles with which it was to have been armed. Insofar as the Arrow itself was concerned, it was decided that a final decision as to the continuation of development and subsequent production of the fighter would be deferred until March.

It would be naïve to assume that the whole flight test programme and work on the present pre-production batch of aircraft will not be abandoned completely if the March reassessment decides against further production, but, at the time of closing for press, two new factors are raising confidence in the Canadian aircraft industry that the government will reverse its apparent plan to change over entirely to missiles for Canada's air defence.

The first of these factors is that of cost. Revised cost estimates for the Arrow in the light of the replacement of the Astra electronic system and Sparrow missiles by a Hughes fire-control system and Falcon missiles available "off-the-shelf" from the USA, together with other economies, will result in a cost from this point on of £1,392,800 per aircraft, against £3,428,800 per aircraft previously quoted, on the basis of an order for one hundred machines. The second factor is that of performance. Even the Arrow Mk. 1, an intermediate development machine powered by Pratt and Whitney J75 turbojets, has exceeded 1,500 m.p.h. (Mach 2.27), the performance predicted for the Arrow Mk. 2 with the lighter and substantially more powerful Orenda Iroquois turbojets, and it is now anticipated that this later model, which is scheduled to commence flight testing at the time of writing, will attain speeds greater than 2,000 m.p.h. (Mach 3.0). Thus, the Canadian aircraft industry will be flying a Mach 3.0 aircraft *this year*—some two years earlier than aircraft of other countries intended for similar performances.

In the autumn of 1952, the RCAF began

SPECIFICATION

TYPE:
Two-seat Medium-range All-weather Interceptor Fighter.

POWER PLANTS:
(Mk. 1) Two 17,500 lb.s.t. (23,500 lb. with afterburning) Pratt and Whitney J75 turbojets. (Mk. 2) Two 22,000 lb.s.t. (30,000 plus lb. with afterburning) Orenda PS-13 Iroquois turbojets.

DIMENSIONS:
Span, 50 ft.; length (without nose probe), 77 ft. 9¾ in.; height, 21 ft. 3 in.; main undercarriage track, 25 ft. 5½ in.; wing area, 1,225 sq. ft.

ARMAMENT:
Eight Hughes Falcon homing missiles or alternative weapons.

WEIGHTS:
(Mk. 2) Normal combat gross weight, 64,000 lb., approximate maximum loaded, 76,000 lb.

PERFORMANCE:
(Mk. 2) Maximum speed, Mach 3.0 plus (2,000 m.p.h. plus); approximate service ceiling, 65,000 ft.; approximate tactical radius (without external fuel), 750 mls. Designed to operate from 6,000-ft. runways.

PILOTS LIKE IT . . .

The following comments have been abstracted from Arrow test pilots' reports: "The nosewheel can be lifted off by very gentle movement of the stick at just over 120 knots." . . . "Unstick speed is about 170 knots A.S.I. with an aircraft attitude of about 11 degrees." . . . "Acceleration is rapid, with negligible correction required and no tendency to swing." . . . "Typical touch-down speed is a little over 165 knots." . . . "There is no indication of stalling at the maximum angle of attack at 15 degrees." . . . "In turns, stick force was moderate to light, but always positive, with no tendency to pitch-up or tighten."

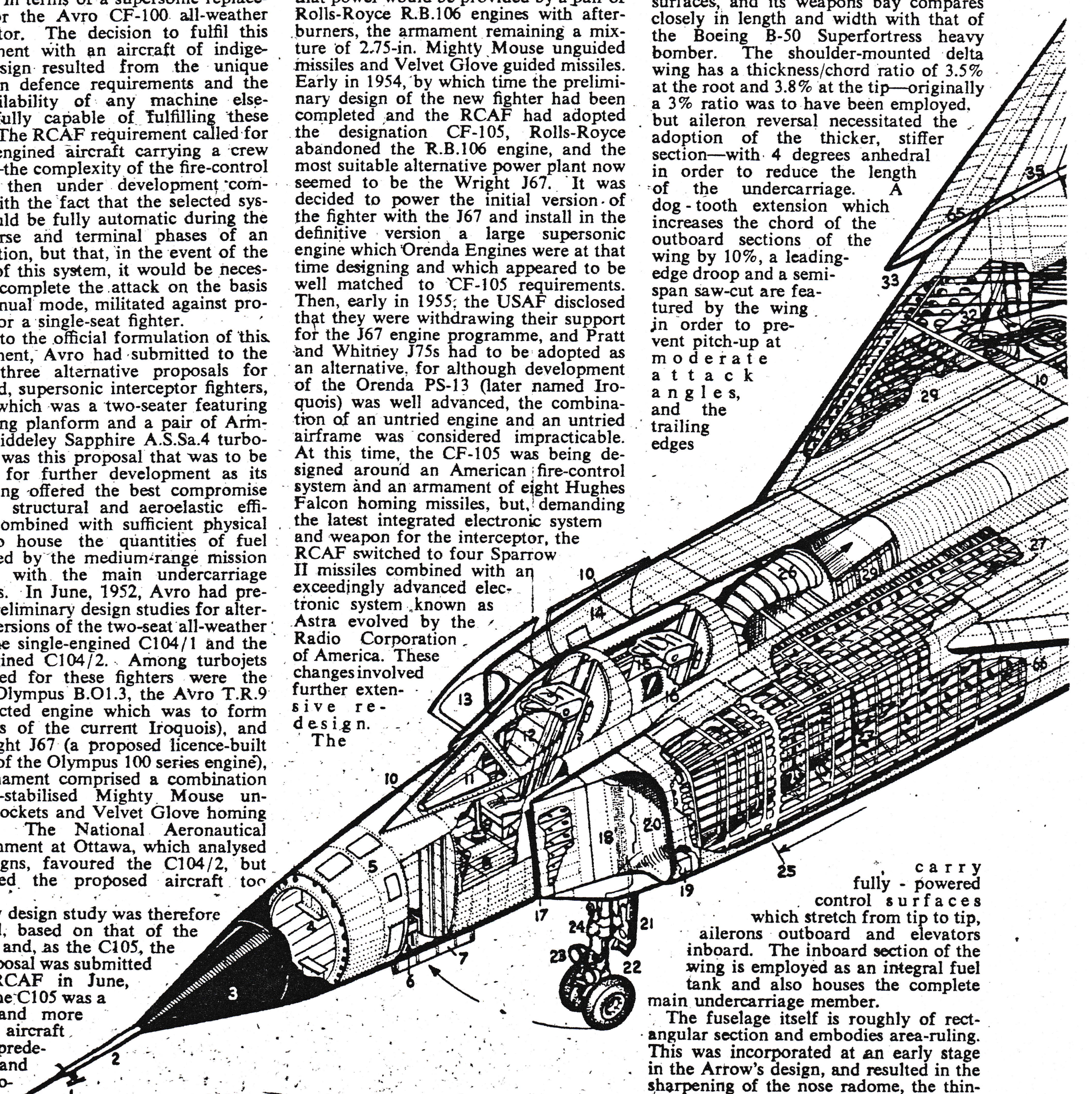
to think in terms of a supersonic replacement for the Avro CF-100 all-weather interceptor. The decision to fulfil this requirement with an aircraft of indigenous design resulted from the unique Canadian defence requirements and the non-availability of any machine elsewhere fully capable of fulfilling these needs. The RCAF requirement called for a twin-engined aircraft carrying a crew of two—the complexity of the fire-control systems then under development combined with the fact that the selected system would be fully automatic during the mid-course and terminal phases of an interception, but that, in the event of the failure of this system, it would be necessary to complete the attack on the basis of a manual mode, militated against proposals for a single-seat fighter.

Prior to the official formulation of this requirement, Avro had submitted to the RCAF three alternative proposals for advanced, supersonic interceptor fighters, one of which was a two-seater featuring delta wing planform and a pair of Armstrong Siddeley Sapphire A.S.Sa.4 turbojets. It was this proposal that was to be selected for further development as its delta wing offered the best compromise between structural and aeroelastic efficiency combined with sufficient physical depth to house the quantities of fuel demanded by the medium-range mission together with the main undercarriage members. In June, 1952, Avro had prepared preliminary design studies for alternative versions of the two-seat all-weather delta; the single-engined C104/1 and the twin-engined C104/2. Among turbojets considered for these fighters were the Bristol Olympus B.O1.3, the Avro T.R.9 (a projected engine which was to form the basis of the current Iroquois), and the Wright J67 (a proposed licence-built version of the Olympus 100 series engine), and armament comprised a combination of spin-stabilised Mighty Mouse unguided rockets and Velvet Glove homing missiles. The National Aeronautical Establishment at Ottawa, which analysed the designs, favoured the C104/2, but considered the proposed aircraft too heavy.

A new design study was therefore prepared, based on that of the C104/2, and, as the C105, the new proposal was submitted to the RCAF in June, 1953. The C105 was a lighter and more compact aircraft than its predecessor, and it was proposed that power would be provided by a pair of Rolls-Royce R.B.106 engines with afterburners, the armament remaining a mixture of 2.75-in. Mighty Mouse unguided missiles and Velvet Glove guided missiles. Early in 1954, by which time the preliminary design of the new fighter had been completed and the RCAF had adopted the designation CF-105, Rolls-Royce abandoned the R.B.106 engine, and the most suitable alternative power plant now seemed to be the Wright J67. It was decided to power the initial version of the fighter with the J67 and install in the definitive version a large supersonic engine which Orenda Engines were at that time designing and which appeared to be well matched to CF-105 requirements. Then, early in 1955, the USAF disclosed that they were withdrawing their support for the J67 engine programme, and Pratt and Whitney J75s had to be adopted as an alternative, for although development of the Orenda PS-13 (later named Iroquois) was well advanced, the combination of an untried engine and an untried airframe was considered impracticable. At this time, the CF-105 was being designed around an American fire-control system and an armament of eight Hughes Falcon homing missiles, but, demanding the latest integrated electronic system and weapon for the interceptor, the RCAF switched to four Sparrow II missiles combined with an exceedingly advanced electronic system known as Astra evolved by the Radio Corporation of America. These changes involved further extensive re-design.

The CF-105 was officially christened Arrow early in 1957, by which time contracts had been placed for thirty-seven development and pre-production machines, the first five of these being Mk. 1s with Pratt and Whitney J75 engines, and the remaining thirty-two being Mk. 2s with Orenda Iroquois turbojets. When the first Arrow Mk. 1 (RL-201) was wheeled out and officially unveiled on October 4, 1957, it was immediately obvious that, aerodynamically, the new interceptor was a considerable advance over contemporary aircraft and a tremendous achievement for the Canadian aircraft industry.

An extremely large, tailless delta, the Arrow Mk. 1 possesses a fuselage stretching 83 ft. 2 in. from the tip of its nose probe to the extremity of its vertical tail surfaces, and its weapons bay compares closely in length and width with that of the Boeing B-50 Superfortress heavy bomber. The shoulder-mounted delta wing has a thickness/chord ratio of 3.5% at the root and 3.8% at the tip—originally a 3% ratio was to have been employed, but aileron reversal necessitated the adoption of the thicker, stiffer section—with 4 degrees anhedral in order to reduce the length of the undercarriage. A dog-tooth extension which increases the chord of the outboard sections of the wing by 10%, a leading-edge droop and a semi-span saw-cut are featured by the wing in order to prevent pitch-up at moderate attack angles, and the trailing edges



carry fully-powered control surfaces which stretch from tip to tip, ailerons outboard and elevators inboard. The inboard section of the wing is employed as an integral fuel tank and also houses the complete main undercarriage member.

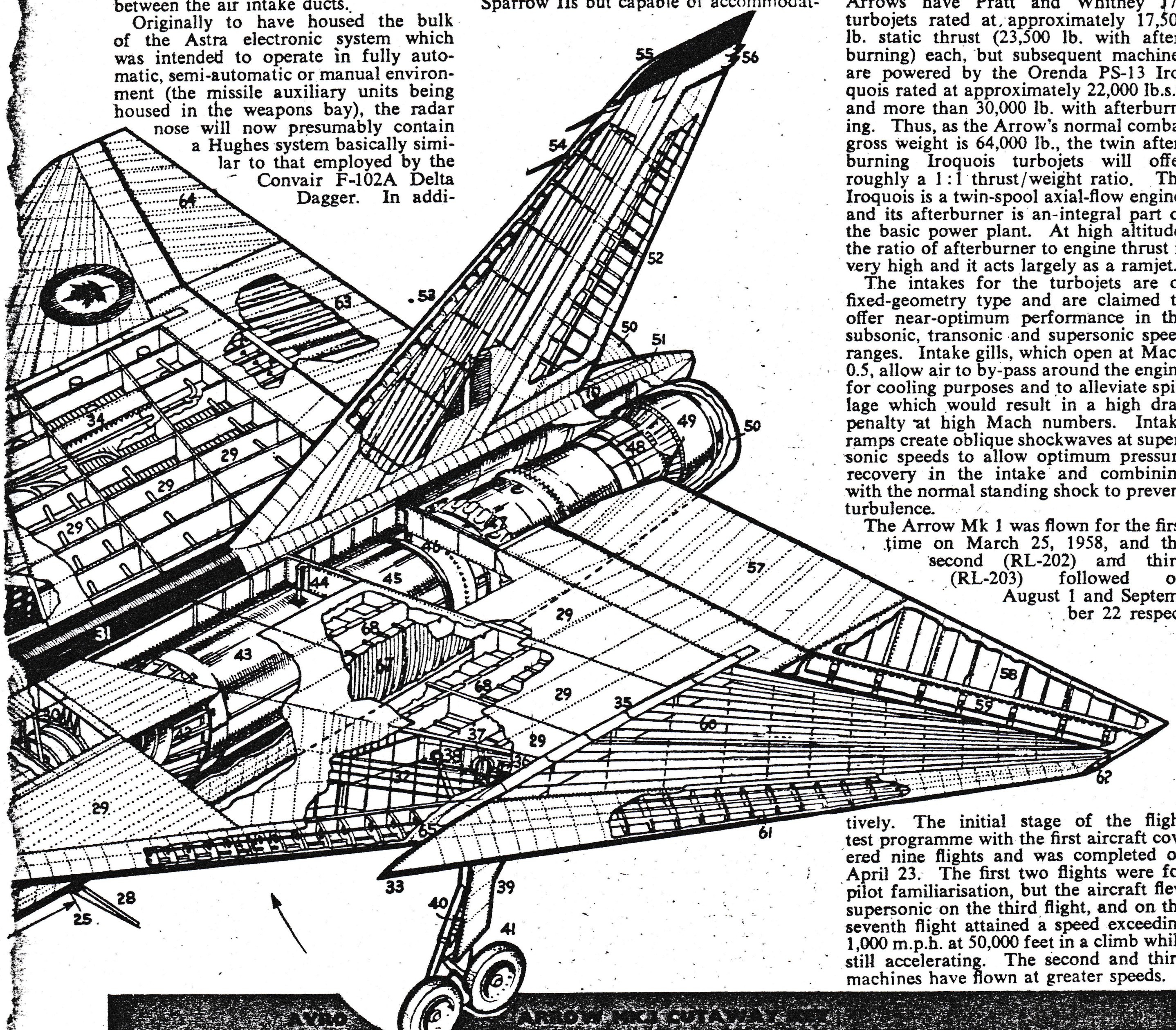
The fuselage itself is roughly of rectangular section and embodies area-ruling. This was incorporated at an early stage in the Arrow's design, and resulted in the sharpening of the nose radome, the thinning down of the intake lips, a reduction in the cross-sectional area below the canopy, and an extension fairing added at the rear to smooth out the area rule curve. The pilot and navigator are seated in tandem Martin-Baker Mk. 4 ejector seats in a fully pressurised cockpit between the air intake ducts.

Originally to have housed the bulk of the Astra electronic system which was intended to operate in fully automatic, semi-automatic or manual environment (the missile auxiliary units being housed in the weapons bay), the radar nose will now presumably contain a Hughes system basically similar to that employed by the Convair F-102A Delta Dagger. In addition, the nose contains the nosewheels and leg, which retract forward. Additional fuel tanks are installed aft of the cockpit, between the intake ducts, and over the turbojets. The immense missile bay, originally intended to house four Sparrow IIs but capable of accommodating a variety of different missiles in detachable packs, spans the full width of the fuselage under the engine air intake ducts and below the forward fuselage fuel tank.

As previously mentioned, the first five Arrows have Pratt and Whitney J75 turbojets rated at approximately 17,500 lb. static thrust (23,500 lb. with afterburning) each, but subsequent machines are powered by the Orenda PS-13 Iroquois rated at approximately 22,000 lb.s.t. and more than 30,000 lb. with afterburning. Thus, as the Arrow's normal combat gross weight is 64,000 lb., the twin afterburning Iroquois turbojets will offer roughly a 1:1 thrust/weight ratio. The Iroquois is a twin-spool axial-flow engine, and its afterburner is an integral part of the basic power plant. At high altitude, the ratio of afterburner to engine thrust is very high and it acts largely as a ramjet.

The intakes for the turbojets are of fixed-geometry type and are claimed to offer near-optimum performance in the subsonic, transonic and supersonic speed ranges. Intake gills, which open at Mach 0.5, allow air to by-pass around the engine for cooling purposes and to alleviate spillage which would result in a high drag penalty at high Mach numbers. Intake ramps create oblique shockwaves at supersonic speeds to allow optimum pressure recovery in the intake and combining with the normal standing shock to prevent turbulence.

The Arrow Mk 1 was flown for the first time on March 25, 1958, and the second (RL-202) and third (RL-203) followed on August 1 and September 22 respectively. The initial stage of the flight test programme with the first aircraft covered nine flights and was completed on April 23. The first two flights were for pilot familiarisation, but the aircraft flew supersonic on the third flight, and on the seventh flight attained a speed exceeding 1,000 m.p.h. at 50,000 feet in a climb while still accelerating. The second and third machines have flown at greater speeds.



AVRO ARROW MK1 CUTAWAY [illegible]

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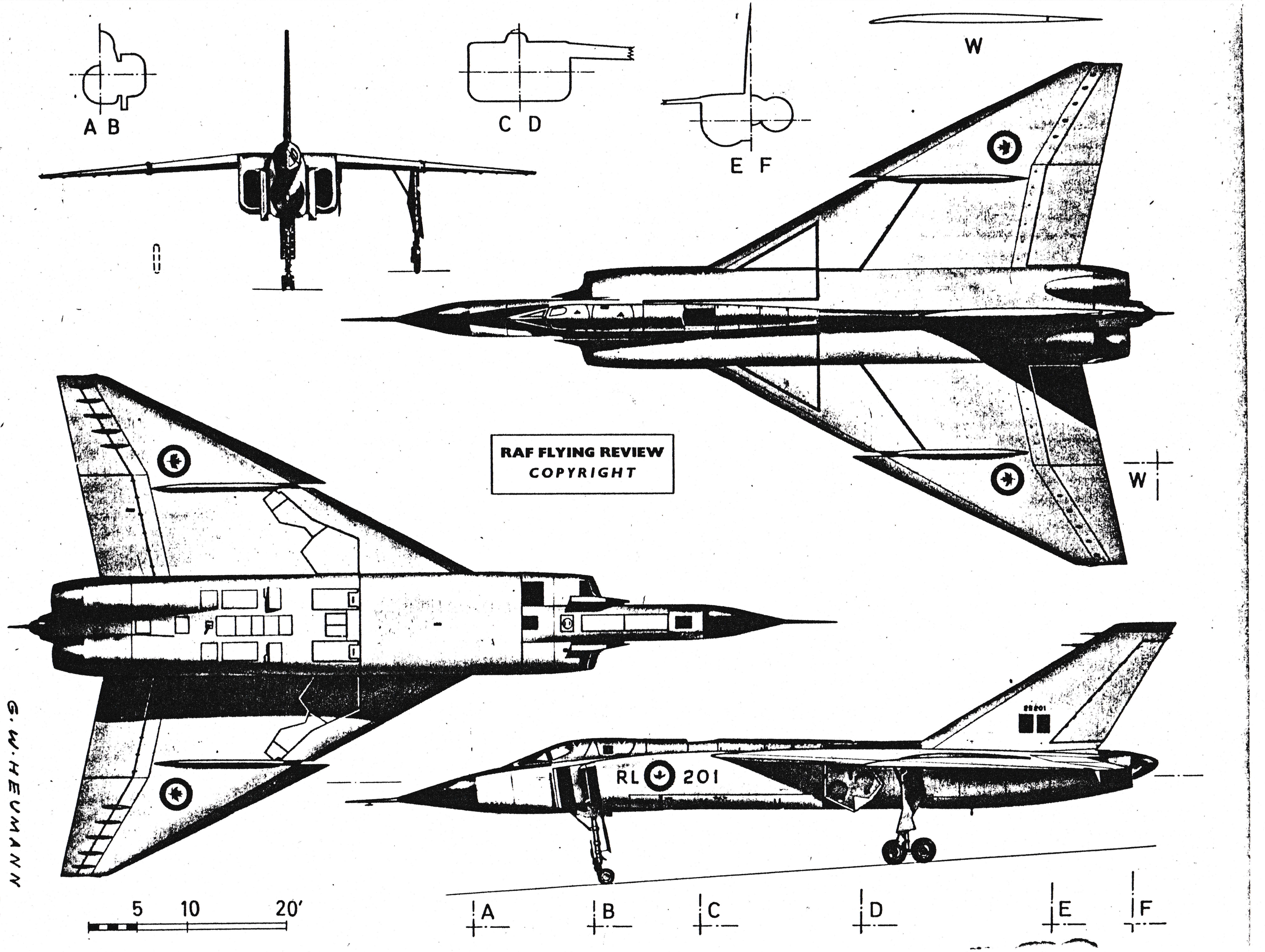
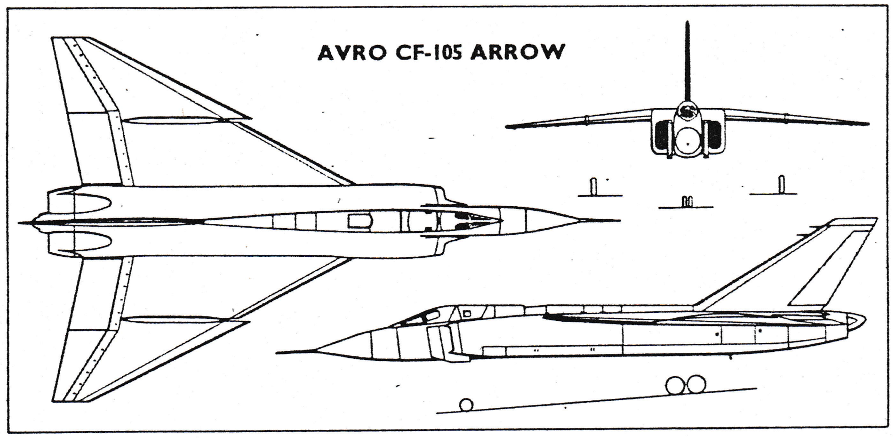
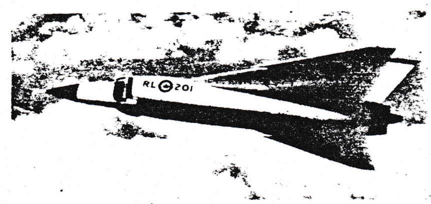
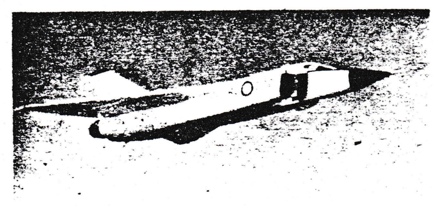
SCALE-PLAN SERIES 51 AVRO CF-105 ARROW MK. 1



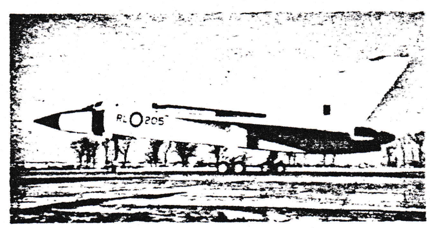




1st Avro CF-105 Arrow



2nd Avro CF-105 Arrow



5th Avro CF-105 Arrow

CANADIAN ARROW

'I recently came across mention of a fighter named Avro Arrow which, apparently, was quite a "hot ship" but came to a somewhat abrupt end. I should like to know something of the history of this machine, and shall be glad if you will publish details, photographs and a general arrangement drawing.

A. G. Owens,
Moreton, Bideford, N. Devon.

The Avro CF-105 Arrow was, at the time of its cancellation on February 20, 1959, undoubtedly one of the most advanced interceptor fighters extant, and few would now argue that the decision by Mr. Diefenbaker, the then Canadian Prime Minister, to terminate the development programme of this aircraft and its power plant after the expenditure of some £108M was not an error of major magnitude; one underlined a mere three years later when it was found necessary to acquire from the U.S.A. the two-seat McDonnell F-101B Voodoo to fulfil the rôle for which the Arrow had been originally intended. At the time of the Arrow's cancellation, Mr. Diefenbaker stated that Canada would rely mainly on the Bomarc surface-to-air missile, although during the tenure of his government, the warheads of the missiles were *sand-filled*, and it is only in recent months that nuclear warheads have been delivered and the Bomarc has become operational.

Originally scheduled to provide the backbone of Canada's air defences in the 'sixties, the CF-105 Arrow passed through a number of major design and equipment changes from the preliminary study in 1953 to the placing of an order for thirty-seven development and pre-production machines four years later. The first five machines (RL-201 to RL-205) were each powered by two Pratt and Whitney J75 turbojets of

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